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A FIELD METHODOLOGY APPROACH BETWEEN AN EARTH-BASED REMOTE SCIENCE TEAM AND A PLANETARY-BASED FIELD CREW[1]

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The Scouting Exploration Methodology Study (SEMS) is a systematic contextual field photo documentation and science data collection process. This process was developed in order for both the field crew and Remote Science Team (RST) to interpret and analyze data for maximum collaboration. Three rotations implemented the SEMS during the 2004 and 2005 field season at the Mars Society's Mars Desert Research Station. The intention of this paper is to demonstrate why a methodology is necessary in planetary field exploration strategies. The emphasis of this paper is to explain the evolution of the SEMS to a final contextual photo documentation methodology which will be implemented by Sklar during the 2006 MDRS field season.

INTRODUCTION

In the study of planetary field exploration, different methodologies will need to be studied, so that both field crews and remote scientists will be able to analyze and collaborate with different datasets. The Scouting Exploration Methodology Study (SEMS) is one such methodology. It will eventually extend to more specialized science goals tailored to respond to questions arising from discoveries on a situational basis. Our definition of planetary also includes asteroids, natural satellites, and extreme earth environments; however, the focus is on Mars surface exploration studies.

Astronauts will be communicating their research and observations to scientists back on earth. The RST are currently filling the role of the backroom scientists on earth in support of science teams at planetary analog sites worldwide. The main goal of our project is to discover the best approach to field operations, data collection, storage, collaboration and analysis from both the planetary field crews and the RST.

BACKGROUND

A number of issues regarding data collection and organization arose during the first four years of operations at both the Mars Desert Research Station (MDRS, Hanksville, Utah) and Flashline Mars Arctic Research Station (FMARS, Devon Island, Canadian Arctic). The authors developed the SEMS project based on the experience gained from field studies at MDRS and FMARS as field crew, Mission Support personnel, and RST members since 2000.[1]

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Prior to the beginning of the FMARS Crew 5 rotation in 2001, a remote science team called the Science Backroom Operations Team selected ten sites based on scientific priority using a LANSAT image of the Haughton Crater region. During the rotation, aerial images were taken of the previous selected sites and then analyzed by the Science Backroom Operations Team to determine what tasks should be done at each of these sites and their associated scientific questions. The analysis done by the team was in the format of annotated images and a list of questions and tasks sent through email to the crew. Based on these recommendations, the crew decided which sites to visit. Next the crew obtained panoramic (Pan) and other images at the sites in question. Some of the Pan images were viewed by the Science Backroom Operations Team at NASA Ames Flight Simulator, a unique situation in that the team could view the site from the same perspective as the field crew within a 360-degree format. The team realized by viewing these images that some of the fluvial activity was not visible within the normal Pan view. Due to time constraints and computer problems, the field crew did not visit all the sites. Some of the lessons learned were that better organization and planning of EVAs, more contextual images, and more communication and collaboration between the field crew and the remote scientists were needed. The most significant research question from the Science Backroom Operations Team at the end of the rotation was "What formats could be implemented for better communication and collaboration?"

During Expedition One (MDRS Crew 14), the contextual approach to field documentation was initiated using data logger devices which included GPS, images, and voice notes. This enabled the remote scientists to view and interpret individual pieces of data, and to continue investigating the types of datasets needed to answer the question "What data need to be collected in order for the remote scientists to know where the field crew is located?” Data was organized by date and EVA number. This made it difficult to interpret, because it was not known which datasets, such as images, were related to which voice notes. Even though GPS was used it was difficult to determine the cardinal directions of site images as well as the macroscopic views that were being investigated. The question then became "How can we organize the data so that both field crew and RST can begin analysis"?

In the first formal investigation of these questions, Crew 21 (MDRS) revisited sites first established by Crew 11 (MDRS). The data used to revisit these sites were in the form of images, GPS, and/or written site descriptions, but even with these datasets only one exact sample match out of five was located. At this point the question then became “What datasets need to be collected in the field so that other crews are able to return to the same site?”

MDRS Crew 25--First Field Use of SEMS

Using all of the lessons learned a field methodology was developed for Crew 25 (MDRS) illustrated in Table 1 and Figure 1. The RST directed this rotation similar to ISS missions. Sites were chosen by rock type (conglomerate, sandstone, shale, etc.) using previous crew’s data. This process developed the following perspectives: Regional, Pan, Outcrop, Rock, Rock in the lab with ruler for scale, and Microscopic. The SEMS established a process during this rotation that could contextually link samples to sites; the backbone of the photo documentation process was established. Further refinement for the contextual process, as well as a collection process for field data, still needed to be investigated. Certain perspective images were not taken at certain sites due to time constraints and unfamiliarity with this process. Tasks associated with each perspective were limited to scale and cardinal direction because this was the first use of SEMS and the crew did not have a geologist.[2]

Perspective	Description
Global	The global perspective should indicate the point where the focusing in process will occur. Spectral or other information can be included in this perspective
Regional	The regional perspective should include an 80 km^3 exploration circle surrounding MDRS so that further operational methodologies can be developed to maximize the exploration circle using all available resources (human (field crew and RST), robotic, and technology)
Local	The local perspective should include an area of 1 km and can also include spectral information as well. This perspective should be easily identified within the regional perspective
Pan	Once a site of interest is located within the local perspective a panoramic (360 degree) image should be taken, document GPS coordinates, scale, cardinal direction, and note geology as well as any possible further research such as stratigraphy of erosional rise NW within Pan image
Outcrop	Once an outcrop is located within the Pan perspective, an image should be taken, document GPS coordinates, scale, cardinal direction, and note geology.
Rock	If a sample will be collected within the outcrop perspective an image should be taken, document GPS coordinates, scale, cardinal direction, and note geology including why sample taken (i.e. sample requested by RST, unusual structure, etc.). Weathered (exterior) surface: Image of rock back at lab with scale (ruler) and note grain size and minerals if present or visible with hand lens. If further lab analysis on rock is conducted indicate what tests were completed (HCL, hardness, streak plate, etc.), take images of different testing results (collaborate with RST if needed). Label samples so correlation of sample numbers are the same as outcrops and slides (microscopic viewing). Fresh (interior) surface: Break rock to show interior and take image of rock with scale (ruler) and note grain size and minerals if present or visible with hand lens. If further lab analysis on rock is conducted indicate what tests were completed (HCL, hardness, streak plate, etc.), take images of different testing results (collaborate with RST if needed). Label samples so correlation of sample numbers are the same as outcrops and slides (microscopic viewing).
Microscopic	Take images both of weathered and fresh surface using the highest magnification available. Note grains and minerals size with scale, if possible identify minerals and describe textures. Label microscopic sample to correlate to rock and outcrop perspectives

Table 1 illustrates the focusing in process of SEMS with description of each perspective.

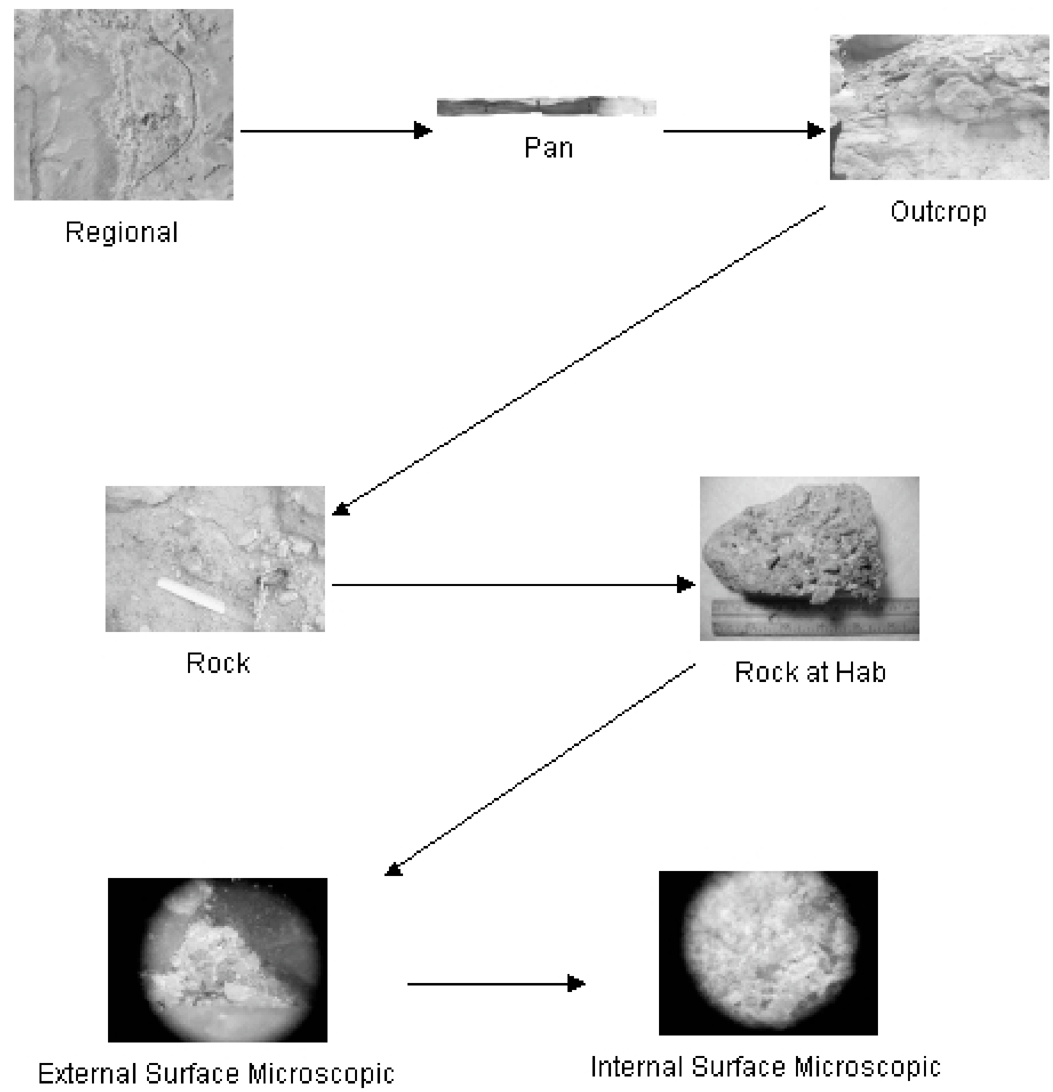

Figure 1 demonstrates how a Compendium map displays the fluid contextual process of each perspective using SEMS for Crew 25.

MDRS Crew 29-NASA Mobile Agents 2004 Field Season

The first Mobile Agents rotation occurred in 2003.[4] The second Mobile Agents rotation involved a complex computer system which included a robot named Boudreaux, repeaters, satellite communication system, differential GPS, speech software, Science Organizer (SO) (the NASA science database), Brahms Agents, and Compendium[5] (a visual work flow software program in the format of contextual maps) assisting a pair of astronauts in the field.[6] Two different scenarios were conducted during the rotation, one at Pooh's Corner and the other at Lith Canyon. The overall system proved highly valuable to both the field crew and the Mobile Agents RST.[7]

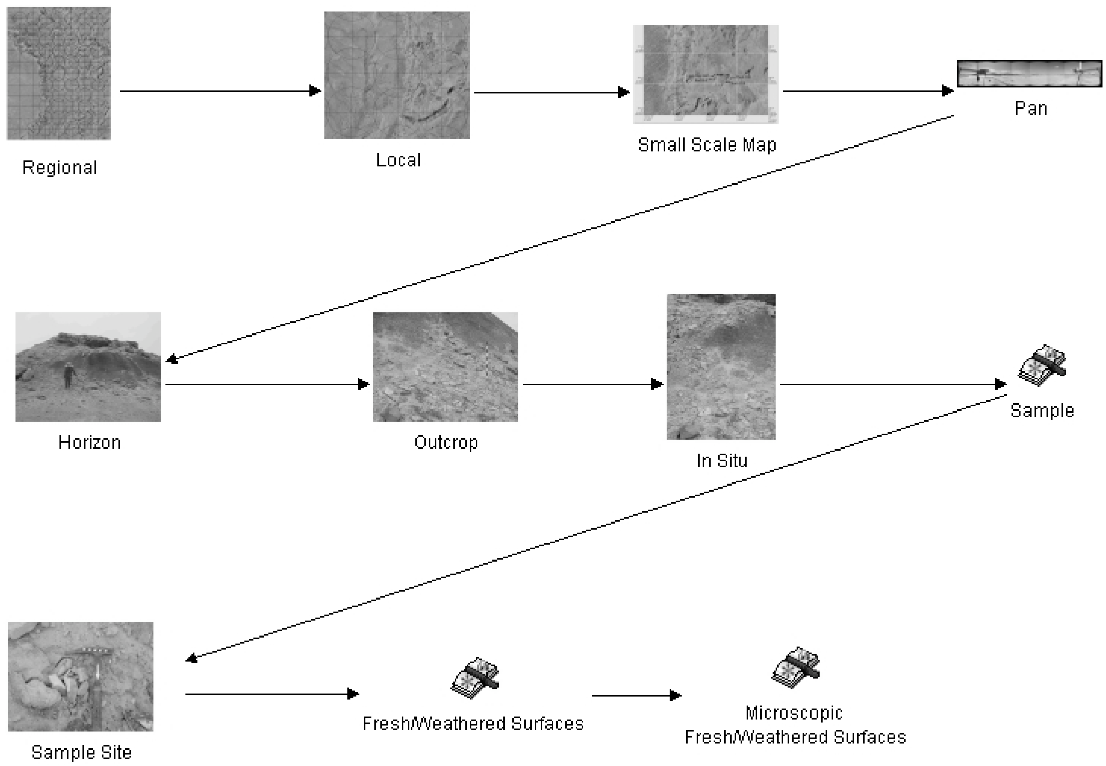

Figure 2 illustrates the Compendium map which displays the fluid contextual process of each perspective using SEMS for Crew 29. Map node without thumbnail image indicates that the image was not taken for this perspective at this particular site.

Field Methodology

From the lessons learned during Crew 25's rotation, the SEMS evolved to the following systematic documentation process which included these perspectives: Regional Map, Local Map, Small Scale Map, Pan, Horizon, Outcrop, In Situ, Sample, Sample Site, Fresh/Weathered Surfaces, and Microscopic Fresh/Weathered Surfaces which is illustrated in Figure 2.

Both the Local Map and Small Scale Map perspectives were added so that both the RST and field crew would be able to view the geology context at a better resolution than the Regional Map image resolution, again using the focusing in approach. Horizon replaced Local in order to convey the focusing in process from the Pan image and to better tie into the Outcrop image. A Horizon perspective criterion is to have the horizon of the site established within this image so that the RST can identify the site within the Pan and Outcrop images. Sample Site Perspective was added to show where samples were taken and Worksite established, but it was not known where Worksite would occur within the process.

Overall, the methodology was followed. Certain perspective images were not taken at certain sites; this was due to time constraints both in the field and in the lab during the Mobile Agents rotation.

Lessons Learned

For the first time, the RST was able to obtain data in a timely manner. A time delay occurred prior to this rotation since crews had to manually download the data obtained in the field once they were back at the Hab. The time delay for the RST to obtain data had been as much as twelve hours. Mobile Agents reduced that time delay to minutes. At Pooh's Corner, cardinal directions were established and for the first time the RST understood the context of the site, located the crew, and knew exactly where samples and images were taken. However, at Lith Canyon the RST could not completely understand the context of the site as well as cardinal directions from the data received.

Possible reasons why the RST had difficulty interpreting this site were: no Pan perspective was taken at the head of the canyon, a misunderstanding of the voice notes that were associated with the site, and Boudreaux not having the ability to descend into the canyon.

It was also difficult for the RST to sift through all the data as it was being downloaded in the form of email. An overwhelming amount of email was sent to the RST via the Brahms agents. Sometimes over a hundred emails were sent during a single EVA. The benefit to using the emails for data analysis was that they were in chronological order. Some RST members deleted the emails before opening them and started to view the data within SO, but this caused problems. SO was able to link the different datasets together only if the field crew first linked the datasets together by association while downloading in the field. Also if the RST wanted to view multiple datasets they could not view these datasets in SO simultaneously in a contextual format.

Compendium solved this problem. Through Compendium maps the RST could view images, voice notes, maps and other data in a simultaneously contextual format. However, the maps had to be downloaded by the field crew for the RST, which recreated the previous problem of a time delay to retrieve data. Also, since the maps were filled with so many data sets the large file size slowed down the data retrieval process. Another unique feature of Compendium was the Portal Map website. This website displayed all of the different Compendium maps used during the rotation. The RST found this website extremely useful and continued to use it to analyze the different datasets. Even though the data retrieval process in a contextual format of a Compendium map was not as quick as the individual pieces of data retrieved through SO or email, it was the preferred format for many of the RST during this rotation.

Science

While the main focus of the Mobile Agents rotation was to test the overall system, a few basic science questions were addressed. This would also test to see where within the SEMS science can be addressed in order for more effective collaboration between the field crew and the RST. The field crew dug a small trench at the eastern base of Red Hill during the Pooh Corner scenario. It appears from this image that the beds are coarsening-upward from a siltstone unit to a mudstone unit to a sandstone unit. This would indicate a transgressive/regressive fluvial environment. A detailed lithology analysis would have confirmed this preliminary analysis. The science question would be to confirm the hypothesis "Is the Pooh Corner site part of a transgressive/regressive environment?" Other questions would be "Is it possible to reconstruct flow regime within the Pooh Corner site?" and "What datasets are needed to make this analysis?" During the Lith Canyon scenario, channel lens data (including channel lag) indicated an ancient meandering-river system. The same question of flow regime from Pooh's Corner applies here as well. The field crew gained access to the head of the canyon by way of a southeastern-sloped ridge. This sloped ridge could possibly be a chute bar or cut bank. If the structure is a chute bar then the maximum current velocity of the channel occurred within this area. The science question then becomes, "How can we determine the velocity of the ancient channel?" If the structure is a cut bank then evidence of a point bar should be present. However, no such evidence was suggested by the data. So then the science question becomes, "What data are needed to confirm cut bank/point bar geometry structure?"

EXPEDITION TWO

Expedition Two occurred in Australia, at the site of the future MARS-OZ station. Data logger equipment (GPS, digital camera, and PDA which included the ability to record voice notes) and GPS Photo-Link software were used in the field in cooperation with the methodology.[8] This was similar to Mobile Agents but a much less complex system. However, significant problems occurred: the track logs that linked the map images to the photo images malfunctioned due to software issues, downloading data could not be implemented due to slow ISP DSL internet connection, GPS-Photo link could not be established because of the track log malfunction, manual GPS input into the track log software revealed that the maps (aerial and topographic) were not available, and regolith could not be identified due to highly vegetated sites. Even with these problems the methodology and field data collection process were further refined, and landforms and rock types were identified. The refinements included how and where images should be taken using the data logger devices as well as further integration and refinement of the data logger devices. These refinements proved instrumental to the success of Expedition Alpha.

EXPEDITION ALPHA[9]

The main goal during Expedition Alpha (ExAlpha) (MDRS Crew 30) was to maximize area coverage of the region surrounding MDRS using the same data logger devices and GPS Photo-Link software as Expedition Two. The whole exploration strategy was termed HERMES in which the SEMS was used for the contextual photo documentation process. [4,10] The scientific objective was to have the field crew and the ExAlpha Remote Geology Team (RGT) view the images obtained using the methodology and determine where concretions could be located. In addition to locating concretion sites, site characterization in the form of regolith terrain mapping, science questions, and Worksite tasks were implemented by analysis of images. Further development of a geological database is needed. Suggestions for the database include integration to GIS mapping, index to papers, Mars Analogs and associated papers, regolith terrain, depositional and sub environment classification, Worksite tasks, and science questions.

[4] HERMES is NOT another photo documentation process as implied by Sklar in the original paper. The author takes full responsibility for any misunderstandings this may have created.

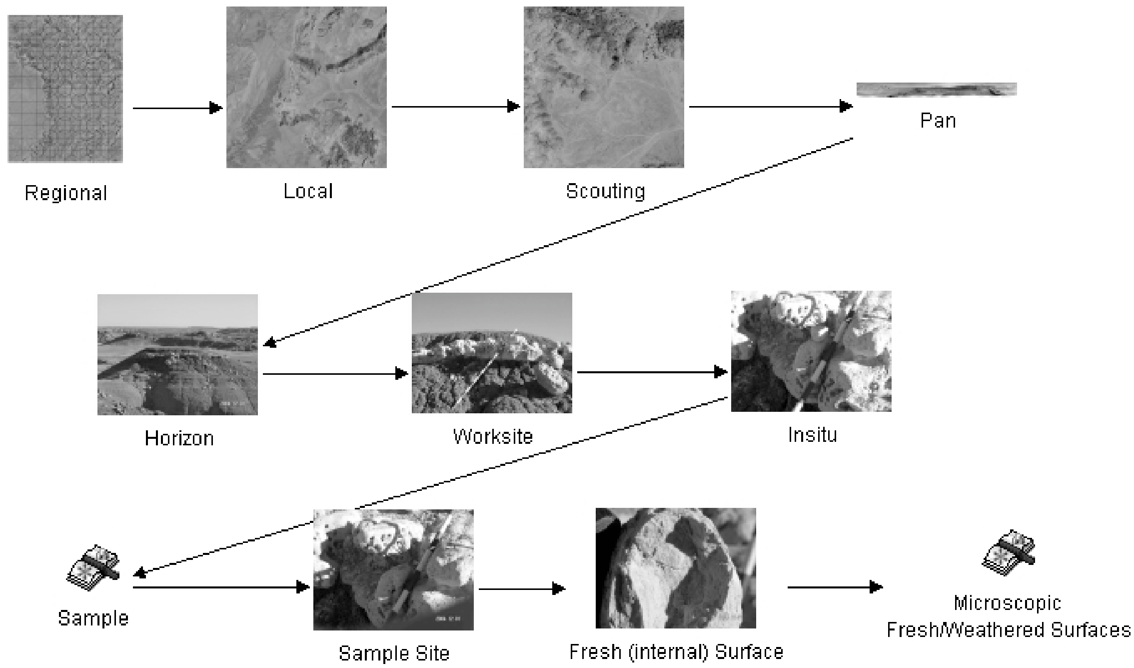

Figure 3 demonstrates how a Compendium map displays the fluid contextual process of each perspective using SEMS for Crew 30. Map node without thumbnail image indicates that the image was not taken for this perspective at this particular site.

Field Methodology

From the lessons learned during Mobile Agents, Expedition Two, and during the first week of Expedition Alpha, the SEMS evolved to the following systematic documentation process which included these perspectives: Regional Map View, Local Map View, Scouting Map View, Pan, Horizon, Worksite, In Situ, Sample, Sample Site, Fresh/Weathered Surfaces, and Microscopic Fresh/Weathered Surfaces illustrated in Figure 3.

Scouting Map View replaced Small Scale Map as part of the mission objectives. One of the operational questions became, "Can the RST view within the Scouting Map what is seen in the Pan Perspective?" Preliminary analysis indicates that, due to elevation, not all of the geology can be seen in both views (Scouting and Pan). This is where the ExAlpha RGT realized that a tie-in between aerial maps images and ground truth Pans is needed. Worksite replaced Outcrop since parameters such as tasks, science questions, interpretation, and analysis will more than likely take place using this perspective. The RGT determined that the detail of the geology imaged at this perspective was better than the original concept of the Worksite defined at the Horizon Perspective. However, these parameters can still be implemented at any of the perspectives. At first the field crew was confused by the flow of the different perspectives, however, after the change to Worksite the workflow became Pan-->Horizon-->Worksite. The RGT believes that the confusion was due to the field crew using the Worksite perspective as the Horizon Perspective. Further research is needed to evaluate this misunderstanding.

The process begins by the Regional View which illustrates an array of circles projected onto an aerial map of the MDRS region, next is the Local View which is a smaller set of the circle array, and the final view for the map section perspectives is the Scouting View perspective. The Scouting View displays the entire diameter of the individual circle.

The Pan perspective begins the ground (field) part of the process. At this point either the field crew chose to use the central point of the circle or chose a bearing from the center of the circle to create a Pan view. Pan image increments were 30°, therefore the Pan image started at the 00° due North and ended at 330°. These images were then stitched together to form the full 360° view at that point. For example, following the naming scheme, the image labeled “Pan D4 Central 330”, is the Pan image taken at the central point of the D4 circle at a bearing of 330°. This would indicate the image's cardinal direction was northwest. This made it easy for both the field crew and RGT to know where the field crew was and the cardinal direction the image was taken. The RGT could go by the naming scheme only and place the location of the field crew and the contextual environment without having to toggle between different GIS datasets. What was surprising for the RGT was that landforms seen from map views could not be identified accurately within the Pan either due to elevation or field of view from the Pan points.

The next step is the Horizon perspective, which is chosen from the Pan perspective, and includes the horizon of a single still image focusing in on one or more particular feature(s). For example, since the mission objective was to locate the best sites for concretions, the team concentrated on looking at sandstone units. Once the Horizon perspective bearing was established from the initial Pan point, following the naming scheme the image labeled “Horizon C4 310”, would indicate that the Horizon image was taken northwest on a bearing of 310° from the Pan point center of circle C4. The next perspectives, Worksite and In Situ, again focused in on the particular feature(s) following the same bearing procedure as Horizon. The bearing procedure not only helped the RGT in location and context but in the traverse path the crew followed in order to reach that particular perspective. If the crew wanted to return to that location they could use the same traverse path by using the route-finding option available on most GPS units.

Tasks associated with each perspective included scale, and with Horizon, Worksite, and In Situ perspectives, the 1/3 rule of photography was implemented. The Fresh and Weathered Surface perspectives as well as the Microscopic perspectives were done in the field. However, at the end of the rotation it was concluded that these perspectives should have been done in the lab.

RESULTS

The Global Perspective was never illustrated during any of the rotations. It was concluded that this piece of data was not necessary since any needed information could be obtained from the Regional Perspective. However, the global perspective should be used when comparing two different sites such as MDRS and FMARS.

It was determined that a new perspective should be added called the Exploration Perspective. The Exploration Perspective should include the largest possible extent of the exploration circle and should be extended to at least a 500 km diameter. If this perspective were covered at MDRS then many scientific sites would be explored such as Meteor Crater (Arizona), the Salt Lakes (Northwest Utah), Grand Canyon (Arizona), and Dinosaur Monument (Northeast Utah). The Regional and Local Perspectives remain the same.

The Scouting Perspective name was changed from the Small Scale Map Perspective, known as the Small Scale Map Perspective during the Mobile Agents rotation. This perspective is the smallest (in lateral extant) of the aerial views. The Pan Perspective will remain the same.

The Horizon Perspective was added during the Mobile Agents rotation. This new perspective was determined to be necessary in order to locate the site between the Pan and Outcrop Perspectives.

The Outcrop Perspective name was changed to Worksite. The RST felt that this reflected a better understanding of a site of scientific interest, since not all sites will have an outcrop to investigate.

Another new perspective that was added during Mobile Agents was the In Situ Perspective. This perspective is necessary in order for the sample that is to be collected is seen within its contextual environment.

The Rock Perspective was renamed Sample Perspective. The RST felt that this reflected a better naming scheme since not all samples will be of geological origin (i.e. biological and/or fossil).

The Sample Site perspective was also added during the Mobile Agents rotation. This perspective was deemed necessary for contextual and scientific purposes after the sample has been collected. For example, if a geological sample was taken could any subsurface biological (i.e. endoliths) be observed?

External/Internal surface and Microscopic Perspectives remain the same. However, it was determined that after the Sample Site the field Methodology is complete. Sample analysis will be completed back at the station.

CONCLUSIONS

Three main sections of the documentation exploration strategy emerged: Aerial Mapping, Field Documentation, and Lab Analysis. The Aerial Mapping section includes Global (when necessary), Regional, Local, and Scouting Perspectives. This section can be thoroughly studied prior to field crew departure and pre planning of EVA's can be outlined according to sites of scientific interest. The Field Documentation section includes Pan, Horizon, Worksite, In Situ, Sample, and Sample Site Perspectives. Robotics can aid the field crew in the collection of this data. Lab Analysis section includes Sample Analysis, External/Internal Sample, and External/Internal Perspectives. The RST can aid the field crew in the analysis of this section once the previous data has been sent to the RST.

Another approach to field exploration strategies was discussed among the RST particularly during the Expedition Alpha Crew. The group concluded that a multi-leveled strategy should be applied, in which surveying, scouting, and investigation would build upon the previous data collected and that some variation of the SEMS would be included. For example, the surveying phase would only include the Aerial Mapping and the Pan. The Scouting phase would build upon the surveying phase to include Horizon and Worksite and the investigation phase would build upon that to include sample collection and Lab Analysis.

Perspective View	Description
Global	Only necessary when comparing two different sites. The global perspective should indicate the point where the focusing in process will occur. Spectral or other information can be included in this perspective
Exploration	The largest possible coverage of the exploration circle, at least a 500 km diameter. Field exploration strategies should be started from this perspective.
Regional	The Regional should include the use of an array of smaller 1 km circles and can also include spectral information as well. This perspective should be easily identified within the exploration perspective
Local	The local perspective should include an area of 1 km and can also include spectral information as well. This perspective should be easily identified within the regional perspective
Scouting	The smallest (in lateral extant) of the aerial views and can also include spectral information as well. This perspective should be easily identified within the local perspective
Pan	Once a site of interest is located within the local perspective a panoramic (360 degree) image should be taken, document GPS coordinates, scale, cardinal direction, and note any sites within this perspective that would be of scientific interest. Example, NW sandstone unit possible endoliths or concretion habitat. This perspective should be easily identified within the scouting perspective.
Horizon	To locate the site between the Pan and Outcrop Perspectives. An image should be taken, document GPS coordinates, scale, cardinal direction, and note any sites within this perspective that would be of scientific interest. This perspective should be easily identified within the pan perspective
Worksite	An image should be taken, document GPS coordinates, scale, cardinal direction, and note any sites within this perspective that would be of scientific interest. This perspective should be easily identified within the worksite perspective
In Situ	A sample that is to be collected is seen within its contextual environment. An image should be taken, document GPS coordinates, scale, cardinal direction, and note any samples within this perspective that would be of scientific interest. This perspective should be easily identified within the worksite perspective

Sample	An image should be taken, document GPS coordinates, scale, cardinal direction, and note why sample taken (i.e. sample requested by RST, unusual structure, etc.). This perspective should be easily identified within the in situ perspective
Sample Site	Image of sample site after sample has been collected record any observations not previously visibly
Sample Analysis	Image of sample in lab including scale, note any structures, and significant observations. Sample will be analyzed further so some structures may be destroyed in this process. However, every measure should be taken that significant structures should NOT be destroyed.
External/Internal Sample	Weathered (exterior) surface: Image of rock in lab with scale (ruler) and note grain size and minerals if present or visible with hand lens. If further lab analysis on rock is conducted, indicate what tests were completed (HCL, hardness, streak plate, etc.); take images of different testing results (collaborate with RST if needed). Label samples so correlation of sample numbers are the same as outcrops and slides (microscopic viewing). Fresh (interior) surface: Break rock to show interior and take image of rock with scale (ruler) and note grain size and minerals if present or visible with hand lens. If further lab analysis on rock is conducted indicate what tests were completed (HCL, hardness, streak plate, etc.), take images of different testing results (collaborate with RST if needed). Label samples so correlation of sample numbers are the same as outcrops and slides (microscopic viewing).
External/Internal Microscopic	Take images both of weathered and fresh surface using the highest magnification available. Note grains and minerals size with scale, if possible identify minerals and describe textures. Label microscopic sample to correlate to rock and outcrop perspectives

Table 2 illustrates the final methodology that Sklar will implement during the 2006 MDRS Field Season.

This approach could then integrate robotics and RST where needed. For example, robotics would collect the surveying data with the RST supervising and analyzing the data to determine where the scouting phases would take place. The scouting phase could be done by all (robotics, field crew, and RST) but the robotics and RST should take the initiative to free the field crew. This places the maximum amount of resources on the investigation phase.

Another strategy that could be applied is within the Local aerial map. How much data is needed to cover the 1 km area? For example, how many pan images are needed in order for the RST to correlate data within aerial imagery to compare to ground truth imagery?

Overall the methodology was followed. However, many field crew members felt that the collection process was rather cumbersome. Dividing the SEMS into sections and using a phase approach would eliminate the large amount of data collection required using SEMS for the field crew. Sklar will use the SEMS displayed in Table 2 during the MDRS 2006 field season and will also apply the phase approach during this rotation with emphasis on the investigation phase. The emphasis will be placed on fossil collection and endolithic observations at known sites near MDRS.

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